Journal of Constructional Steel Research 71 (2012) 129–142

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Shear strength of panel zone in beam-to-column connections

Giuseppe Brandonisio *, Antonio De Luca, Elena Mele

Department of Structural Engineering, University of Naples "Federico II", Naples, Italy

ARTICLE INFO

Article history:
Received 14 May 2011
Accepted 5 November 2011
Available online 9 December 2011

Keywords:
Panel zone
Beam-to-column connection
Shear strength
FEM analysis

ABSTRACT

The paper deals with the problem of evaluation of the panel zone (PZ) shear strength in beam-to-column connection. To this aim, the mechanical behaviour of the PZ and the European and American code provisions for the design of PZ are examined and critically discussed. Non-linear FEM analyses and experimental tests carried out on beam-to-column steel connections are also provided and compared with both European and American practices.

Both numerical and experimental results have shown a good agreement with the American provisions. On the contrary, some drawbacks are identified in the application of European provisions, which cause overestimation of the PZ shear strength of about 50–60%. These differences could cause invalidation of the capacity design approach to the steel moment resisting frames, which in the case of European provisions should lead to strong panel zone, where the possibility of PZ yielding is precluded. Therefore, an improvement to the European code provisions is suggested in order to better evaluate the PZ shear strength.

1. Introduction

Steel Moment Resisting Frames (MRFs) are widely used in high seismic areas due to their inherent ductility as well as large flexibility in the architectural planning. The seismic performance of MRFs depends on the cyclic behaviour of its major elements, i.e. columns, beams and connections.

The response of the beam-to-column connections, particularly in the case of welded connections, is strongly affected by the panel zone (PZ), which is defined "by the column web area delineated by the extension of beam and column flanges through the connection, transmitting moment through a shear panel" [1].

Wide experimental and analytical studies have been carried out starting from the '70s, mainly by Krawinkler et al. [2], Bertero et al. [3], and Popov [4], in order to examine the behaviour of PZ under monotonic and cyclic loadings. These pioneering studies have demonstrated that the behaviour of the panel zone is highly ductile, and characterised by significant strength reserve after first yielding, as well as by stable and wide hysteresis loops. Further studies have been carried after the 1994 Northridge earthquake [5–10] showing that excessive shear distortions could create brittle ruptures at the welds of beam-to-column connection. The results obtained from these research activities have reflected in the subsequent changes and modifications proposed to the design approach in the American and European codes. In particular, it has become clear that the presence of PZ should be explicitly considered in the capacity design of MRFs structures, and the conventional strength hierarchy should be enlarged also to account for the PZ. In fact, excluding the possibility of formation of plastic hinges in the columns (strong column philosophy), in the case of MRFs, it is possible to have three different scenarios [4]. The first one ensures that the PZ remains elastic during the earthquake, forcing all plastic deformations to occur in the beams ("strong PZ–weak beam" philosophy: SPZ–WB). The second approach concentrates all inelastic deformations in the PZ ("weak PZ–strong beam" philosophy: WPZ–SB). The third design philosophy is a compromise between the above two approaches; indeed both PZ and beam participate in the seismic energy dissipation ("intermediate" design philosophy).

The question to allow or not the yielding of the PZ, is still a topic of discussion in the research community [11], as a matter of fact, in European seismic codes a strong PZ is prescribed, whereas in the US design practices, the yielding of the PZ is allowed.

In any case, whichever is the assumed design approach, allowing or not for the PZ yielding, it is of fundamental importance having an accurate evaluation of panel zone shear strength, as well as a proper limitation of PZ slenderness in order to avoid the PZ shear buckling with consequent reduction of PZ strength and of PZ dissipative capacity.

Previously, the issue of shear buckling in the panel zone of beam-to-column connections was examined by the authors. Specifically in [12]: i) elastic and inelastic buckling theories for rectangular plates under shear stress have been studied; ii) design provisions of both American and European codes have been critically reviewed; iii) a FEM parametric analysis on beam-to-column connections characterised by different aspect ratios and PZ slenderness, has been carried out. Finally, iv) experimental data, retrieved from bibliography, have

* Corresponding author.
E-mail address: giuseppe.brandonisio@unina.it (G. Brandonisio).

0143-974X/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jcsr.2011.11.004